Original paper

REGIONAL DISTRIBUTION OF GHG EMISSIONS FROM LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT IN THE REPUBLIC OF MACEDONIA IN THE PERIOD 2007-2012

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Abstract

The estimation of GHG emission from domestic livestock in the Republic of Macedonia during the period from 2007-2012 is performed according to the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories applying the Tier 1 method for calculation of emissions. This article has accepted the following gasses: Methane (CH_4), Nitrous oxide and CO_2-eq from the domestic livestock sub sector using data sources from the official Statistical Yearbooks of the Republic of Macedonia. According to available data for livestock species, distribution of total annual methane emission and nitrogen excretion was calculated in each planning region for the period 2007-2012. In the analyzed period two regions showed continuously highest (Southeast region) and lowest (Vardar region) CH_4 emission and nitrogen excretion. In the period 2007-2012 CH_4 emission ranged between 26.43 Gg (2007) and 23.78 Gg (2012), with the lowest value in 2012 (23.78 Gg). Depending on the animal waste management system the highest value for nitrogen excretion (solid storage and drylot) was observed in 2010 (kt/N/yr). Almost similar value for nitrogen excretion from pasture and paddock was observed in 2007 and 2008, 9.54 and 9.53 kt/N/yr respectively, with the lowest value for analyzed period noted in 2009 (8.82 kt/N/yr). In this period the highest value (3.32 kt/N/yr) for other type of AWMS was recorded in 2007. Separation of certain regions in the country regarding GHG emission can be clearly noted. Data for the period 2007-2012 show a downward trend in GHG emission. Applications of modern breeding technology, balanced feed as well as better feed quality in the future are the main objectives in order to reduce GHGs emission from this subsector.

Key words: *livestock, methane, nitrous oxide and CO_2-eq*

Introduction

Livestock production can be noted as a major contributor to the environmental pollution, because this sector is contributing in emission of GHG in the form of CH_4 from enteric fermentation, and CH_4 and N_2O from manure management and deposition of animal manures on pastures. According to FAO (2006) livestock contributes 18% of global GHG emissions although emission is highly variable in different regions. The global dairy sector contributes from 3.0% to 5.1% of the total anthropogenic GHG emissions (FAO, 2010). Livestock GHG emissions by IPCC inventory system equals to 10.8% of global emissions according to FAO

(2006) and this ector constitute nearly 80% of agricultural emissions. Denman et al. (2007) and EPA (2006) calculate values of 8 and 9.6%, respectively, of livestock's contribution to global agriculture emissions. Comparing data mentioned above livestock's contribution to global GHG emissions is in the range of 8 up to 10.8%.

Greenhouse gas emissions from livestock are closely related to the number of each animal species and different categories inside the species. Main impact on GHG emission is from ruminants, especially cattle. Besides the number of animals, general factors that have their influence on emission levels are: size of animals, productivity level of animals, system of manure management, type of diet, type of production system and the climate conditions in the region.

Methane emissions in the period 2003–2009 account for 12.38% of total GHG emissions in Macedonia. One third of emissions is generated by enteric fermentation and manure management, and as a consequence these emissions are directly proportional to livestock numbers. High amount of CH_4 emissions (89%) are generated by enteric fermentation from domestic livestock, and these emissions have been continuously decreasing as a result of reduction of livestock populations. Manure management emissions account for 8% of GHGs, while the remaining emissions come from rice fields and the burning of residues. N_2O emissions from the management of agricultural soils are 89%, including the use of fertilizers, the amount and type of manure applied, leaching, nitrogen-fixing crops and atmospheric deposition, while remaining emissions are generated by manure management and to a less significant extent, from the burning of crop residues (Zdraveva et al., 2013).

This paper shows the greenhouse gas emissions from the livestock production sector in the Republic of Macedonia during the period 2007-2012. To obtain more precise information on GHG, emissions were calculated for each state statistical region separately in order to determine the influence of each region in the total annual emission.

Materials and methods

Official data from the State Statistical Office (SSO 2007, SSO 2008, SSO 2009, SSO 2010, SSO 2011 and SSO 2012) were used as entrance data in order to calculate GHGs emission. Data were processed according to the Tier 1 method (IPCC, 1997), which is actually a simplified method of calculation of greenhouse gas emissions. Tier 1 method includes the following data: number of each animal species regarding breeding category and data for climate conditions in the analyzed region which in turn define emission factors/coefficients. The application of the sophisticated Tier 2 method requires detailed information about the livestock sector. The study covers the main animal species in the country: cattle (dairy and non dairy), small ruminants (sheep and goats), pigs, poultry and horses.

Results and discussion

If we compare total annual CH_4 emissions from enteric fermentation (Figure 1) during the analyzed period (2007-2012), highest emission values are present in the Southwest region. From total CH_4 emission in the country 21% of total CH_4 emissions from enteric fermentation in 2011 and up to 24% in 2009 belong to this region. Second region in the country, regarding GH_4 emission is the Pelagonia region. Contribution of this region to total annual emissions ranges between 16% and 22% of total CH_4 emissions from enteric fermentation. Same values (22%) were noted in both regions in 2009 and 2012. Emissions from other regions in the country were lower compared with Southwest and Pelagonia regions. Contribution to total annual CH_4 emission with less than 15% is present in Vardar region, with a value of 5 to 7% of total annual CH_4 emission.

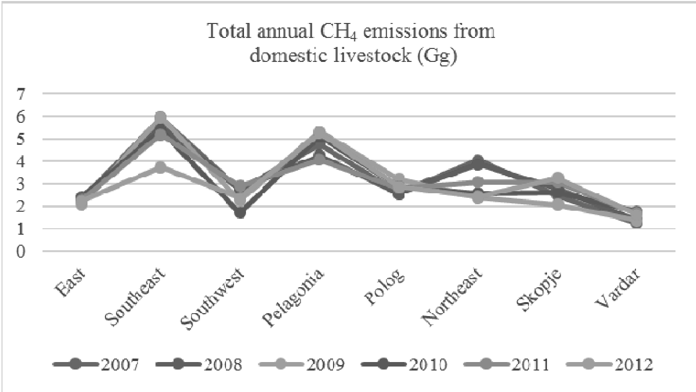

Figure 1. *Methane emission from eight regions in the country*

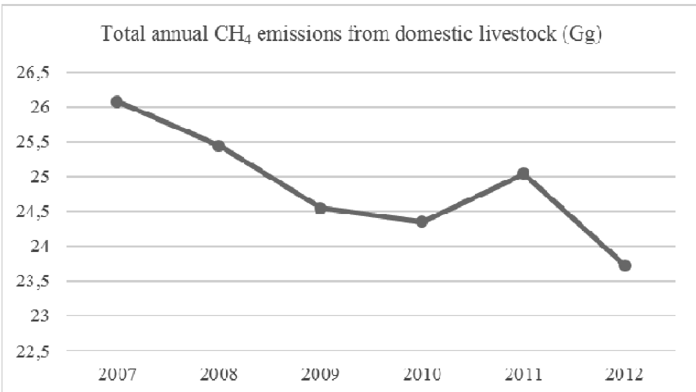

Figure 2. *Total methane emission in the country*

Total annual emission of CH_4 (Figure 2) from enteric fermentation at country level during the analyzed period showed a decreasing tendency. Highest value was noted in 2007 (26.43 Gg) and lowest value in 2012 (23.78 Gg). Management system, composition of manure, the type of bacteria responsible for manure decomposition, presence of oxygen and fluid in the manure management systems significantly affect production of N_2O during the process of manure management. Manure aerobic decomposition is characterized with increased emissions of N_2O, transformation of N_2O in NO results in a reduction of ozone. Lowest values for nitrogen excretion from solid storage and drylot for non-dairy cattle during the analyzed period (2007-2012) were noted in the Vardar region, while highest nitrogen excretion was present in the Southeast region (Figure 3).

Opposite to nitrogen excretion from solid storage and drylot for non-dairy in dairy cattle breeding, highest values were continuously noted in the Pelagonia region with the exception of 2011, when the highest part of total emission was present in the Southeast region (Figure 4).

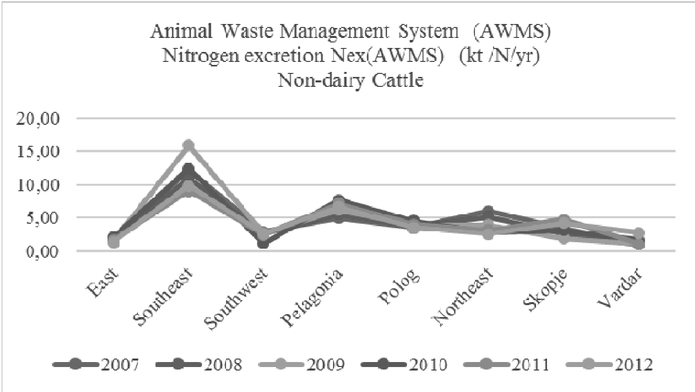

Figure 3. *Total annual* $Nex_{(AWMS)}$ *excretion, non - dairy cattle*

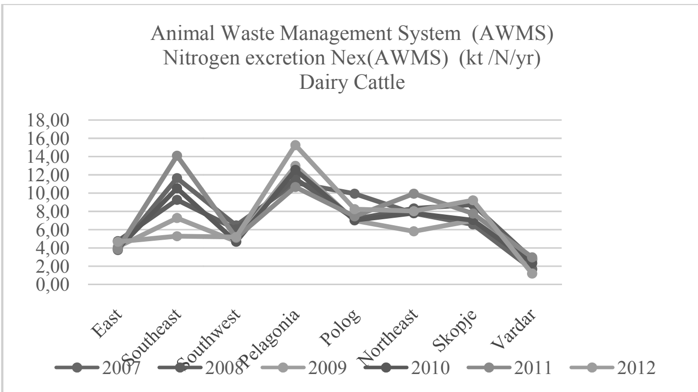

Figure 4. *Total annual* $Nex_{(AWMS)}$ *excretion, dairy cattle*

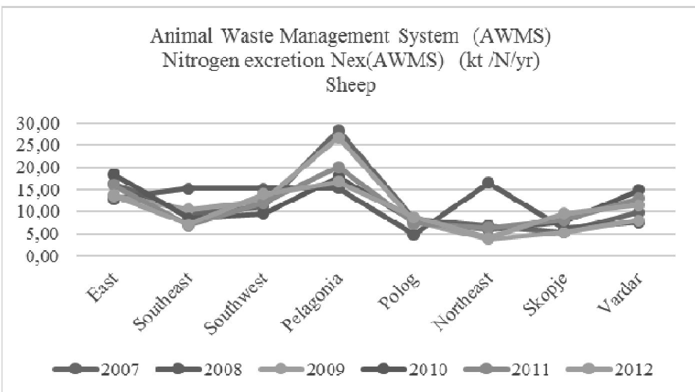

Figure 5. *Total annual* $Nex_{(AWMS)}$ *excretion, sheep*

Reducing the sheep number in Macedonia directly affects nitrogen excretion from pastures and paddock. Two regions (East region and Pelagonia) in the country continuously had the highest nitrogen excretion during the analyzed period, while the Northeast region has the lowest contribution in the analyzed period (Figure 5). Nitrogen excretions from poultry (Figure 6) were highest in the Southeast region until 2009, but at present leading regions are Pelagonia and Polog. Lowest excretion was present in the East region of the country.

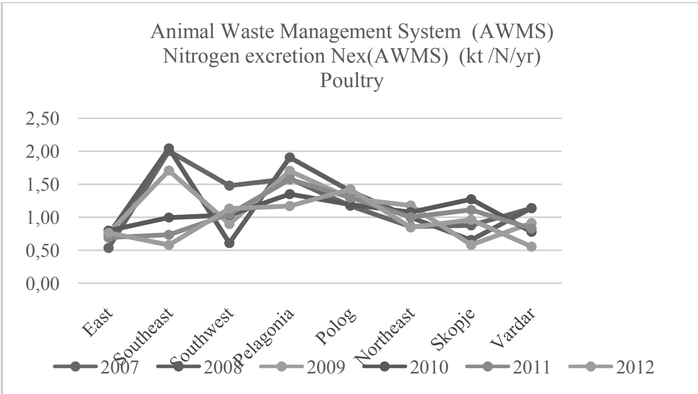

Figure 6. *Total annual* $Nex_{(AWMS)}$ *excretion, poultry*

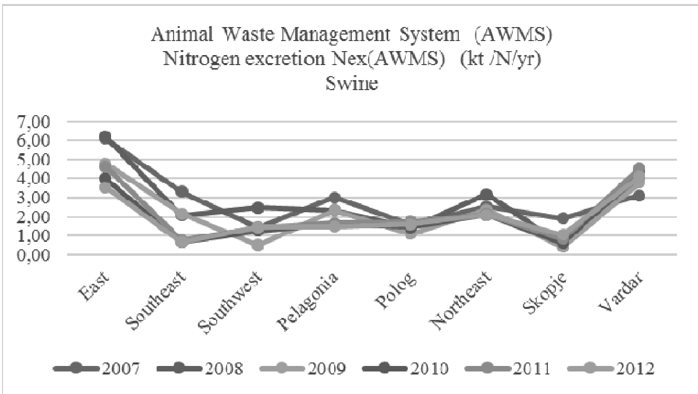

Figure 7. *Total annual* $Nex_{(AWMS)}$ *excretion, swine*

Due to the location of swine breeding in the East and Vardar regions of the country, nitrogen excretion in the analyzed period was higher in those two regions, while lowest values were noted in the Polog and Southeast regions (Figure 7).

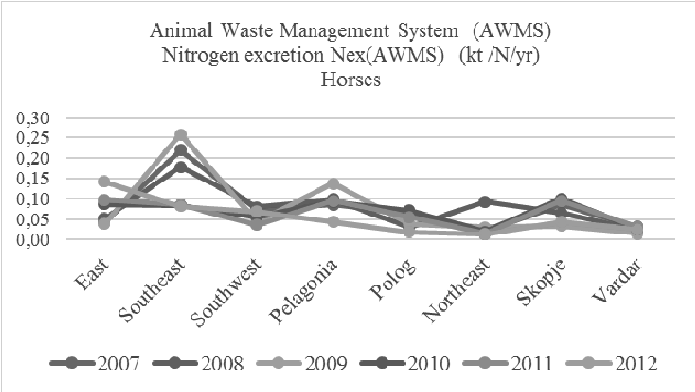

Figure 8. *Total annual Nex$_{(AWMS)}$ excretion, horses*

Highest share from overall nitrogen excretion from horses AWMS in the period 2007-2009 was noted in the Southeast region, in the Pelagonia region in the period 2010 and 2011 and in the East region in 2012, while the Vardar region had the lowest share (Figure 8).

Data for annual emission of N_2O from solid storage and drylot are shown in Figure 9, from other type of AWMS in Figure 10 and from pasture range and paddock in Figure 11. Similar to obtained results for CH_4 emission and nitrogen excretion, high levels of annual emissions of N_2O are mainly located in the Southeast and Pelagonia region for solid storage and drylot (Figure 9). For other type of AWMS (Figure 10) highest levels of annual emissions of N_2O were recorded in the East and Vardar region. The Pelagonia region was the leading region in the country regarding annual emission of N_2O from pasture range and paddock AWMS (Figure 11).

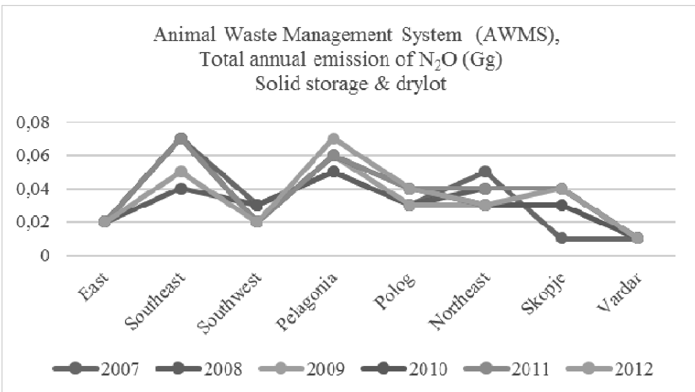

Figure 9. *Total annual emissions of N_2O from dairy and non-dairy cattle*

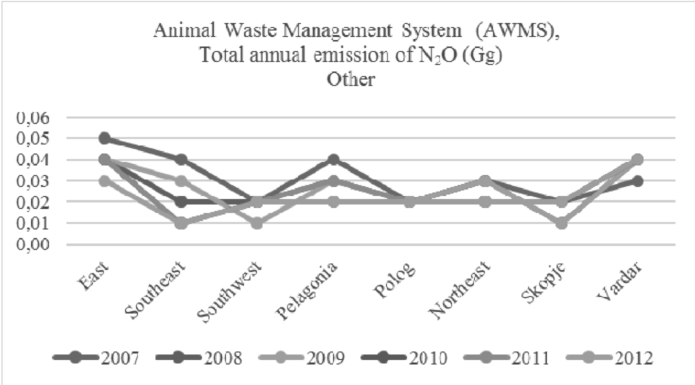

Figure 10. *Total annual emissions of N_2O from other types*

Carbon dioxide equivalent (CO_2-eq) is a metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP). In the analyzed period Southeast region had highest emission level for CO_2-eq from enteric fermentation followed by Pelagonia region, while the lowest value was recorded in Vardar region (Figure 12). CO_2-eq emission from all types of AWMS during the period 2007-2012 was highest in the Pelagonia region.

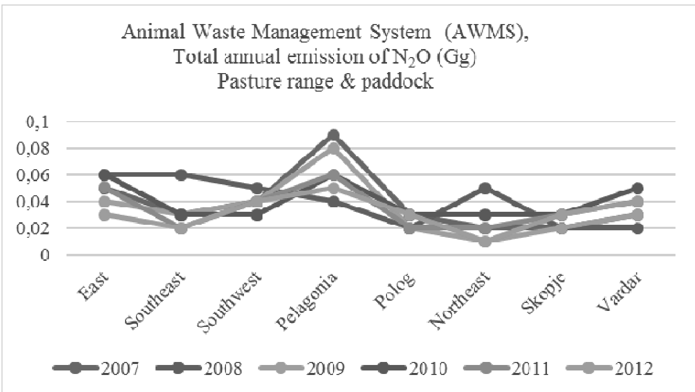

Figure 11. *Total annual emissions of N_2O from sheep*

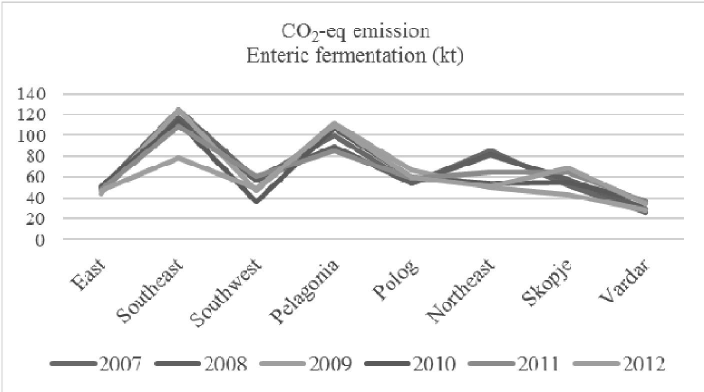

Figure 12. *Annual CO_2-eq emission, enteric fermentation (kt)*

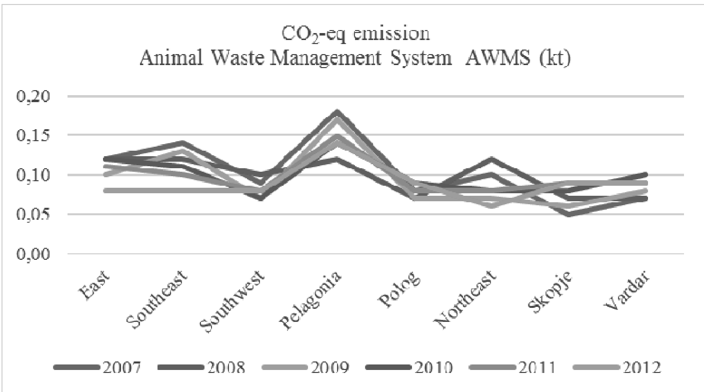

Figure 13. *Annual CO_2-eq emission, Animal Waste Management System AWMS*

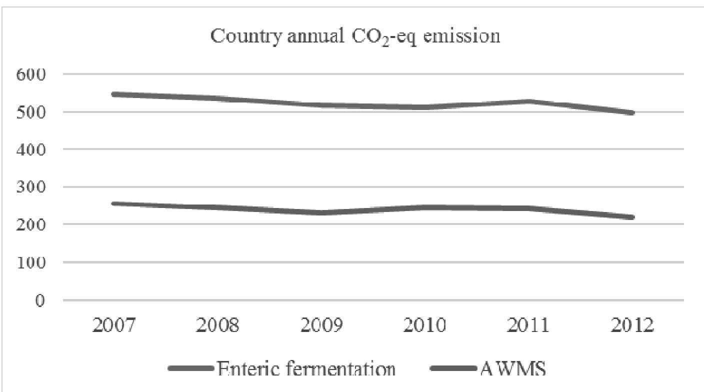

Figure 14. *CO_2-eq emission, per year*

Integral component of the whole process of digestion of plant material in ruminants is the formation of methane. High proportion of CH_4 emission (87%) during the enteric fermentation is a result of the activity of the rumen and the lower part of small intestine (13%) (Murray et al., 1976). Animal type, age, size, quantity of feed, fodder and fodder intake and the lactation period have a significant impact on methane emission in animals (Jungbluth et al., 2001). During the manure management CH_4 emissions are also present, although still significantly lower than emissions from enteric fermentation. Main component of the manure is the organic matter which under the influence of methanogenic bacteria is digested to methane. Methane emission calculation between different manure management systems is primarily based on the amount of manure (depending on the type, category and number of animals) as well as the fraction of manure that is anaerobically decomposed (connected to the climate conditions in the region) (Džabirski et al., 2008).

Regarding CH_4 emissions from enteric fermentation from different regions in the country it is obvious that all regions do not have an equal contribution in the overall CH_4 emission from enteric fermentation. Differences in emission levels are connected with the climate conditions in each region and the level of development of agriculture. These factors are connected and they have influence on the development of the livestock sector and the presence of certain domestic animal species in the region. In Southwest and Pelagonia regions that have a higher contribution in CH_4 the emissions from enteric fermentation come from different breeding categories of the same species (cattle). In the Southwest region non – dairy cattle is more dominant, while in the Pelagonia region the dairy cattle is dominant. There are also differences in species distribution throughout the country, with the number of sheep during the analyzed period continuously increasing in the Pelagonia region, while the number of animals in the other regions only slightly increasing (East region). Poultry from the Southeast region is transferred to Polog and Pelagonia region and swine breeding is dominantly present in the East and Vardar regions.

Variations in the number of domestic animals, unchanged breeding technology but also composition of the diet of animals directly affect the volume of CH_4 emissions from enteric fermentation. CH_4 emission had a decreasing tendency during the analyzed period with the lowest value in 2012 (23.78 Gg). Slight increasing of CH_4 emission in 2011 compared to 2010 is a result of light increase in the number of cattle in the country.

More factors (management system, composition of manure, the type of bacteria responsible for manure decomposition, presence of oxygen and fluid in the manure management systems) significantly affect N_2O production during the manure management process. High levels of nitrogen excretion in the Southeast region are connected with the highest number of bovine in this region.

The Pelagonia region is the leading region in nitrogen excretion from dairy cattle followed by Southeast region. Continuously low contribution was present in the Vardar region (less than 5 %).

Due to highest concentration of poultry breeding in the Pelagonia and Polog regions, nitrogen excretion is higher in those two regions compared to other regions in the country. The East and Vardar regions are the leading regions in nitrogen excretion from swine AWMS. In the first three years of the analyzed period more than 29 % of the overall nitrogen excretion from horses AWMS was present in the Southeast region of the country, with the highest value recorded in 2009 when this region was responsible for the excretion of 44% of the overall nitrogen excretion from horse AWMS.

Highest amount of annual emission of N_2O in the analyzed period was recorded in Southeast and Pelagonia regions. Annual emission of N_2O from solid storage and drylot is mainly connected to number of animals and the presence of any variation has a direct influence on emission levels. Bovine breeding in these two regions in the country is responsible for more than 40% of total annual emission of N_2O, with lowest values for the analyzed period recorded in the Vardar region.

More than one third of total annual emission of N_2O from other type of AWMS was present in East and Vardar regions. Main reason for the predominant emission of N_2O in these two regions is the high concentration of poultry and swine. The dominance of the Pelagonia region in the total annual emission of N_2O over the other regions is connected with the number of sheep in this region.

Different gases have different global warming capacity, and their capacity can be defined as the effect of a gas on climate change. Universal standard unit of measurement by which the various gases can be assessed is CO_2-eq. That enables converting greenhouse gases into a common unit of measurement.

Cattle, at a global level, are the largest contributor to total sector emissions covering approximately 65 % of total livestock sector emissions or 4.6 gigatonnes of CO_2-eq. Depending on type of cattle production, average emissions can be between: 2.8 kg CO_2-eq per kg of fat and protein corrected milk in dairy production and 46.2 kg CO_2-eq per kg of carcass weight for meat production. Globally, pork production is estimated to emit 9 % of the livestock sector emissions or approximately about 668 million tonnes of CO_2-eq. Chicken supply chains emit GHG emissions of 606 million tonnes of CO_2-eq (Gerber, et al., 2013).

Southeast region was the leading region in CO_2-eq emission from enteric fermentation in the first three years of the analyzed period due to the highest number of breeding cattle in all categories. In the next three years the leading region in annual emission of CO_2-eq from enteric fermentation was the Pelagonia region as a result of increased sheep number in the region. These two regions are responsible for more than one third of the total annual emission of CO_2-eq from enteric fermentation in the country.

Small ruminants at a global level represent close to 6.5% of the sector's global emissions, or 475 million tonnes of CO_2-eq, of which 62.94% are allocated to meat production, 27.36% to milk production and 9.68% to other goods and services. Average emission intensity for small ruminant meat is 23.8 kg CO_2-eq/kg, with no large differences between sheep and goat meat (Gerber et al., 2013). Due to highest concentration of ruminants in the Pelagonia region, as well as others species present in this region, first of all poultry, annual emissions of CO_2-eq from AWMS in this region are in the range of 15% of the total annual emission of CO_2-eq from AWMS in 2008 up to 23% in 2009.

At country level in the analyzed period emission of CO_2-eq form enteric fermentation and AWMS are decreasing as a result of overall reduction of livestock.

Reduction in the formation of CH_4 during the enteric fermentation can be achieved through the use of granular foods while improperly balanced feed and the appearance of a lack of protein or minerals would also result in an increased level of CH_4 production. Breeding technology and animal waste management directly affects the amount of produced CH_4 and it has particular impact on cattle breeding, where the formation and emission of CH_4 is lower at fixed breeding system (using balanced diet and a higher level of grains) in respect to pasture breeding (Ominski and Wittenberg, 2006).

Conclusion

Main influence of GHGs emission levels from livestock has the annual livestock number, breeding categories in each species as well as breeding technology. Separation of certain regions in the country regarding GHG emission can be clearly noted. Pelagonia and Southeast regions are connected to cattle breeding and the highest emission of GHG emission (CH_4) from enteric fermentation is present in those two regions. Main sheep breeding regions in the country are East and Pelagonia regions, therefore CH_4 and nitrogen excretion from this specific AWMS are mainly located in these regions. The Eastern and Vardar region of the country are main regions of nitrogen excretion from swine breeding.

Overall GHG emission presented as CO_2-eq emphasize two main regions in the country, Pelagonia and Southeast regions, responsible for emission of more than one third of overall CO_2-eq emission in the country.

Data for the period 2007-2012 show a downward trend in greenhouse gas emissions. Applications of modern breeding technology, balanced feed as well as better feed quality in the future are the main objectives in order to reduce GHGs emission from this subsector. Application of further more sophisticated methods for estimation of GHGs is tightly connected with the application of a system for integrated administration as well as with possession and application of sophisticated equipment.

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